

Biological Affinities and Adaptations of Bronze Age Bactrians: IV. A Craniometric Investigation of Bactrian Origins

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ABSTRACT Discovery of a previously unknown Bronze Age civilization (Oxus civilization) centered on the oases of Central Asia revealed the presence of large, preplanned urban centers immediately above sterile soil. Given the absence of local antecedents, the sudden appearance and proliferation of these Oxus civilization urban centers in the oases of Bactria and Margiana immediately raised the issue of where the inhabitants of these urban centers came from. Three hypotheses have been offered by archaeologists to account for the origins of Oxus civilization populations. These include the early influence model, the late colonization model, and the trichotomy model. Eleven craniometric variables from 12 Aeneolithic and Bronze Age samples, encompassing 657 adults from Central Asia, Iran, and the Indus Valley, are compared to test which if any of these hypotheses are supported by the pattern of phenetic affinities possessed by the Oxus civilization inhabitants of the north Bactrian oasis. Craniometric differences between samples are compared with Mahalanobis generalized distance (d^2), and patterns of phenetic affinity are assessed with two types of cluster analysis (WPGMA, neighbor-joining method), multidimensional scaling, and principal coordinates analysis. Results of this analysis provide no support for either the late colonization model or the trichotomy model but do offer some support for the early influence model. Nevertheless, it is clear that the early influence model fails to account for a shift in interregional contacts, perhaps from western China to the north around 2000 BC, that appears to have played a major role in the origins of the Oxus civilization inhabitants of the north Bactrian oasis. *Am J Phys Anthropol* 108:173–192, 1999. © 1999 Wiley-Liss, Inc.

During the 1960s and '70s, a series of excavations by Soviet archaeologists revealed the existence of a previously unknown Late Bronze Age civilization (c. 2200–2000 BC) (Hiebert, 1994; Kohl, 1992) in southern Central Asia (Askarov, 1977, 1981; Masson, 1988; Masson and Sarianidi, 1972). Various labels have been applied to this civilization: the “Namazga Civilization” (Kohl, 1981), the “Bactrian Civilization” (Askarov, 1977; Sarianidi, 1977; Tosi, 1988; Ligabue and Salvatori, 1988), and the “Oxus Civilization” (Francfort, 1989; Hiebert, 1994; Lamberg-Karlovsky, 1994a,b), this civi-

lization features large urban centers marked by large fortresses with defensive towers, specialized craft areas, and sophisticated irrigation systems located within the oases of Margiana in eastern Turkmenistan and in the northern, southern, and eastern Bactrian oases of southern Uzbekistan and

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northeastern Afghanistan (Askarov, 1977; Askarov and Shirinov, 1994; Sarianidi, 1977, 1981, 1990). Excavations of these urban centers yielded a rich array of fine wheel-thrown ceramics, vessels, disks, and miniature columns of alabaster, numerous objects made of bronze, and beads made from semiprecious stones, gold, and silver (Hiebert, 1994; Hiebert and Lamberg-Karlovsky, 1992; Lamberg-Karlovsky, 1993; Kohl, 1984, 1992; Masson, 1992b; Sarianidi, 1981, 1985, 1987, 1990, 1994). Yet these excavations also revealed that these urban centers appear in the archaeological record fully planned and without any apparent local antecedents (Gupta, 1979; Hiebert, 1994; Hiebert and Lamberg-Karlovsky, 1992; Kohl, 1981, 1984, 1992; Masson and Sarianidi, 1972). Given the absence of local antecedents, the sudden appearance and proliferation of these Oxus civilization urban centers in the oases of Bactria and Margiana immediately raised the issue of where the inhabitants of these urban centers came from.

ORIGINS OF THE OXUS CIVILIZATION

Archaeologists are currently divided over the most likely explanation for the origins of Oxus civilization inhabitants. Proponents of the early influence model suggest that the distinctive features of the Oxus civilization have direct antecedents in the Aeneolithic Geoksyur culture (c. 4800–3000 BC) (Kohl, 1992) located in the Tedjen River delta of southcentral Turkmenistan (Gupta, 1979; Hiebert, 1994; Isakov, 1994; Kohl, 1981, 1984, 1992). These features include controlled irrigation (Kohl, 1981; Lisitsina, 1969, 1978; Masson and Sarianidi, 1972; Tosi, 1973–1974), an oasis-based settlement strategy consisting of a fortified central urban center surrounded by a network of smaller secondary villages (Gupta, 1979; Khlopin, 1964; Kohl, 1981, 1984, 1992; Masson, 1968; Tosi, 1973–1974), and an economic exchange system that placed a premium upon extensive contacts with neighboring regions for importation and exportation of commodities (Atagarrayev and Berdiev, 1970; Khlopin, 1964; Masson, 1992a,b; Sarianidi, 1968, 1990; Vinogradov et al., 1965).

At the end of the Aeneolithic period (c. 3000 BC), the Tedjen River delta appears to

have significantly retracted to the south, and all of the Tedjen sites are abandoned except for the small site of Khapuz-depe. Proponents of the early influence model suggest that although some of the inhabitants of the Geoksyur culture likely took refuge at Khapuz-depe or in the nearby urban center of Altyn depe in the Kopet Dag foothill plain, the presence of Geoksyur-style ceramic scatters and anthropomorphic figurines in the northwestern region of the Margiana oasis in eastern Turkmenistan (Masimov, 1979; Masson, 1992a; Sarianidi, 1993) and at the site of Sarazm in the middle Zeravshan Valley of central Uzbekistan (Isakov, 1981, 1994; Isakov and Lyonnet, 1988; Kohl, 1981, 1984, 1992; Masson, 1992a,b) may indicate that an even greater number fled to the northeast. Emphasizing the cultural parallels between the Aeneolithic Geoksyur culture and the Late Bronze Age Oxus civilization as well as evidence of contacts near Margiana and Bactria, proponents of the early influence model suggest that limited but significant gene flow between the refugees of the desiccated Tedjen River delta and local Neolithic populations in Margiana and Bactria (Hissar culture) (Vinogradov, 1979; Tosi, 1988) account for the origin of Oxus civilization populations.

The second hypothesis for the origin of Oxus civilization populations is the late colonization model. This model holds that the oases of Margiana and Bactria were unoccupied prior to the Initial Late Bronze Age (before c. 2200 BC) (Kohl, 1992) and hence the populations that comprised this civilization must have come entirely from outside. Proponents of this model suggest that Middle Bronze Age (Namazga V: c. 2500–2000 BC) (Kohl, 1992) ceramic wares from the urban centers of the Kopet Dag foothill plain (Altyn depe, Namazga-depe) provide the best prototypes for the characteristic artifact assemblages of with the Oxus civilization (designated as the Bactrian-Margiana Archaeological Complex (BMAC) [Hiebert, 1994]).

According to these researchers, the end of the Middle Bronze Age (c. 2200–2000 BC)

(Kohl, 1992) witnesses an "urban crisis" in which the large urban centers of the Kopet Dagh foothill plain are marked by a dramatic reduction in size or complete abandonment. Although the cause of this urban crisis is unclear, proponents of the late colonization model assert that this crisis led to a wholesale exodus out of the Kopet Dagh foothill plain and a direct colonization of Margiana and eventually Bactria (Askarov, 1974, 1977, 1981, 1988; Biscione, 1977; Gupta, 1979; Hiebert, 1994; Hiebert and Lamberg-Karlovsky, 1992; Lamberg-Karlovsky, 1993, 1994b; Masimov, 1979; Masson, 1981, 1988, 1989, 1992b; Masson and Sarianidi, 1972).

The third hypothesis for the origin of Oxus civilization populations may be described as the trichotomy model. Largely formulated as a response to the late colonization model, the trichotomy model represents the most complex effort to account for the origins of Oxus civilization populations. Presenting it in its most basic form, proponents of the trichotomy model make four assertions to contend that three separate populations may have contributed to the eventual composition of Oxus civilization populations (Francfort, 1984, 1989; P'yankova, 1993; Udemuradov, 1988).

The first assertion is that the oases of Bactria and Margiana were inhabited by a local, Neolithic population long before the appearance of the Oxus civilization in the Late Bronze Age (Dupree, 1973; Jusupov, 1977; Masson and Sarianidi, 1972; Vinogradov, 1979). The second assertion is that proponents of the late colonization model have been overzealous in claiming an absolute homogeneity in material culture in Bactria and Margiana and that in fact significant differences exist between these two regions in expression of the Bactrian-Margiana archaeological complex (e.g., see Gupta, 1979; Hiebert, 1994; Hiebert and Killick, 1993; Kohl, 1984; Masimov, 1981; Masson and Kiiatkina, 1981; Sarianidi, 1993; Terekhnova, 1990). The third assertion is that these differences in material culture between Bactria and Margiana may reflect divergent histories of outside influence across these two regions. Finally, proponents of the trichotomy model assert that the presence of

the Harappan outpost of Shortughai in the eastern Bactrian oasis immediately prior to the appearance of the Oxus civilization may signal possible gene flow from Harappan-affiliated populations into the local resident population of Bactria (Francfort, 1984). By contrast, early appearance of Late Phase Middle Bronze Age (c. 2300–2200 BC) artifacts in the Kelleli sub-oasis of Margiana (Biscione, 1977; Hiebert, 1994; Kohl, 1992; Masimov, 1981; Masson, 1988, 1992a; Sarianidi, 1981, 1987, 1990; P'yankova, 1993; Udemuradov, 1987) may indicate gene flow from the urban centers of the Kopet Dagh foothill plain (Altyn depe) into a preexisting resident population in Margiana (P'yankova, 1993; Udemuradov, 1988).

Hence, proponents of the trichotomy model not only argue that the origins of Oxus civilization populations involve contributions from three separate sources but also that the array of these contributions differed dramatically between Bactria and Margiana. In Bactria, Oxus civilization populations were the product of a local resident population that experienced gene flow from Harappan-affiliated populations whose ultimate origins may be found in the Indus Valley. While in Margiana, the origins of Oxus civilization populations may be traced to a local resident population that experienced gene flow from Middle Bronze Age populations of the Kopet Dagh foothill plain (Altyn depe).

AIM OF THIS STUDY

The purpose of this study is to compare craniometric variation among Oxus civilization inhabitants of the north Bactrian oasis of southern Uzbekistan with Aeneolithic and Bronze Age samples from Iran, the Kopet Dagh foothill plain, the Tedjen River delta, and the Indus Valley to test which of the hypotheses advanced by archaeologists best explain the origins of Oxus Civilization populations. Inclusion of samples from the Kopet Dagh foothill plain and from the Tedjen River delta in the current study permits a more fine-grained assessment of the origin of Oxus civilization populations than was possible in previous analyses (Hemphill, 1998; Hemphill et al., 1997, 1998). Since all of the samples included in this study derive

TABLE 1. *Samples considered in the study*

Code	Maximum sample size		Site/region	Period	Dates	Reference
	Males	Females				
ALT	38	40	Altyn depe/Turkmenistan	Namazga V	2500–2200 BC	Kiiatkina (1987) This report
CEMH	13	18	Harappa/Indus Valley	Late Harappan	1900–1600 BC	Gupta et al. (1962)
DJR	16	32	Djarkutan/North Bactria	Djarkutan phase	2000–1800 BC	Hemphill (1998)
GKS	38	32	Geoksyur/Turkmenistan	Namazga III	3500–3000 BC	Kiiatkina (1987) This report
HAR	23	41	Harappa/Indus Valley	Mature Harappan	2500–2000 BC	Gupta et al. (1962) Hemphill et al. (1991)
KUZ	12	9	Djarkutan/North Bactria	Kuzali phase	1800–1650 BC	Hemphill (1998)
MOL	18	26	Djarkutan/North Bactria	Molali phase	1650–1500 BC	Hemphill (1998)
SAP	13	26	Sapalli tepe/North Bactria	Sapalli phase	2200–2000 BC	Hemphill (1998)
SHS	45	43	Shahr-i Sokhta/Eastern Iran	SHS I, II, III	3000–2200 BC	Pardini and Sarvari-Negahban (1976) Pardini (1977, 1979–1980)
TH2	9	7	Tepe Hissar/northern Iran	Tepe Hissar II	3500–3000 BC	Krogman (1940)
TH3	102	36	Tepe Hissar/northern Iran	Tepe Hissar III	3000–1750 BC	Krogman (1940)
TMG	9	11	Timargarha/Indus Valley	Late Bronze/Early Iron	1400–800 BC	Bernhard (1967)

from sedentary, agricultural communities and from sites that differ little in latitude, a comparison of craniometric variation should suffer no systemic biases due to differences in masticatory stresses or natural selection for dramatically different environments (see Hemphill, 1998).

MATERIALS AND METHODS

Materials

Aeneolithic and Bronze Age skeletal samples from Central Asia, Iran, and the Indus Valley are relatively few in number and are often recovered in fragmentary condition. Nevertheless, 12 samples, numbering 657 individuals (336 males, 321 females) may be compared to assess patterns of biological affinity within and across these regions of the Indo-Iranian borderlands (Table 1). Eleven cranial variables (four for the neurocranium and seven for the facial skeleton) of those defined by Martin (1928) were obtained from all samples and provide the metrical basis for the current study (Table 2). These variables were selected to provide comparability and maximum sample size for pooling individuals recovered from Altyn depe and Geoksyur (see below).

TABLE 2. *Craniometric variables used to generate Mahalanobis generalized distances (d^2) between samples*

	Variable ¹
Neurocranium	
Maximum cranial length (GOL)	1
Maximum cranial breadth (BEB)	8
Minimum frontal breadth (BFTB)	9
Facial skeleton	
Upper facial height (NPH)	48
Nasal height (NH)	55
Nasal breadth (NB)	54
Orbital height (OH)	52
Orbital breadth (OB)	51a
Bizygomatic breadth (BZB)	45
Internal palatal length (IPL)	62
Internal palatal breadth (IPB)	63

¹ Numbers of the variables as defined by Martin (1928).

The samples included in this analysis date to Aeneolithic and Bronze Age contexts from the north Bactrian oasis, the Kopet Dagh foothill plain, the Tedjen River delta (Geoksyur Oasis), the Indus Valley, and Iran (Fig. 1). All samples span a relatively narrow timeframe between 3500 and 800 BC.

The site of Sapalli tepe represents the most thoroughly documented Oxus civilization settlement in the north Bactrian oasis (Askarov, 1974, 1977, 1981). During the course of excavations at Sapalli tepe, 125

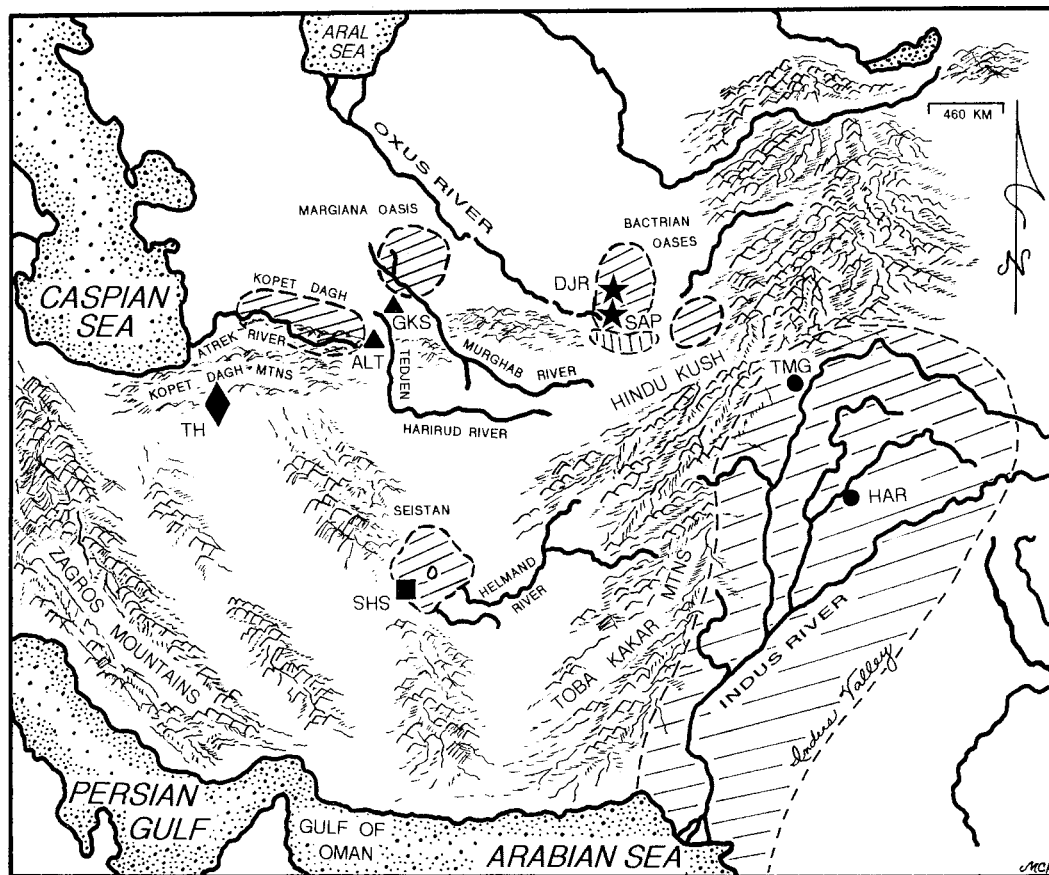


Fig. 1. Geographic location of craniometric samples. Sample abbreviations from Table 1. Oxus civilization samples are represented by stars, northern Iranian samples by a diamond, eastern Iranian samples by a

square, Indus Valley samples by circles, and Turkmenian samples by triangles. Abbreviations for samples are defined in the text.

single and 13 collective burials were located within the habitation area under house floors and walls. Silk remains and hundreds of millet seeds found in these graves have led Kohl (1981, 1984) to postulate that these remains may indicate possible contacts with western China. All human remains recovered from Sapalli tepe have been assigned by Askarov (1977) to the Sapalli phase of the Oxus Civilization. A single radiocarbon date (2009 BC) (Hiebert, 1994) suggests a time span for the Sapalli phase between 2200 and 2000 BC.

Excavations of the Bronze Age site of Djarkutan in the north Bactrian oasis led to discovery of a large cemetery south of the habitation area (Askarov and Abdullaev,

1983; Askarov and Sirinov, 1991, 1994). Partial excavation of this cemetery resulted in recovery of 113 adult individuals with cranial remains. Unlike Sapalli tepe, exposure of these graves failed to yield any evidence of either silk or millet (Askarov and Abdullaev, 1983). These human remains have been assigned to three successive chronological phases: the Djarkutan (DJR) phase (2000–1800 BC), the Kuzali (KUZ) phase (1800–1650 BC), and the Molali (MOL) phase (1650–1500 BC) (Abdullaev, 1979).

Located 50–100 km northeast of the Kopet Dagh foothill plain, the Tedjen River delta was initially occupied at the end of the Early Aeneolithic period (c. 4250–4000 BC) (Khlopin, 1963; Kohl, 1992). Over the course of

the fourth millennium BC, a total of nine sites were established in the delta, but not all were occupied at the same time (Khlopin, 1964; Gupta, 1979). Geoksyur represents the largest of these sites and appears to be the main urban center of the entire oasis (Gupta, 1979; Khlopin, 1964; Kohl, 1981, 1984, 1992; Masson and Sarianidi, 1972). Based upon the appearance of new decorative motifs on ceramic wares, the introduction of gray wares, and the first use of alabaster, some authorities believe that the Late Aeneolithic inhabitants (Namazga III: 3500–3000 BC) (Kohl, 1992) of Geoksyur represent recent immigrants from northern Iran (Masson and Sarianidi, 1972; Sarianidi, 1965). Others, however, believe that there is no evidence for immigration from Iran and that the material culture of the Late Aeneolithic represents a purely indigenous development (Gupta, 1979; Khlopin, 1964; Kohl, 1992). Burials at Geoksyur were recovered from a separate cemetery that encompassed a series of circular semisubterranean collective tombs (*tholoi*) covered by a truncated cone-shaped superstructure made of mud brick. Kiiatkina (1987) measured 42 Geoksyur individuals both on site and in Dushanbe, Tajikistan. A total of 64 individuals from Geoksyur are curated at the Institute of Ethnography and Anthropology of the Russian Academy of Sciences, Moscow, and were examined by the author.

Initially discovered in 1929 by A.A. Semenov and later excavated by Masson (1981, 1988), the site of Altyn depe represents the second largest (26 hectares) and best documented Middle Bronze Age (c. 2500–2200 BC) (Kohl, 1992) urban center in the Kopet Dagh foothill plain of southcentral Turkmenistan. Altyn depe was clearly a large regional urban center, possibly surrounded by a fortification wall, with monumental architecture (ziggurat) and divided into a number of craft areas and residential blocks (Gupta, 1979; Kohl, 1981, 1984, 1992; Tosi 1973–1974; Masson, 1981, 1988, 1992a; Masson and Sarianidi, 1972). Middle Bronze Age burials derive from two inhumation contexts: individual graves located in abandoned sections of the city and collective graves located near living quarters (Masson, 1988; Masson and Kiiatkina, 1981). Kiiat-

TABLE 3. Repeated measures analysis of variance of Geoksyur and Altyn depe crania¹

Variable	N	F	P
GOL	70	0.001	0.973
BEB	79	0.001	0.977
BFTB	79	0.053	0.819
NPH	80	0.030	0.863
NH	80	0.002	0.963
NB	83	0.314	0.577
OH	77	0.019	0.891
OB	75	1.777	0.187
BZB	47	0.017	0.896
IPL	64	1.245	0.269
IPB	58	0.807	0.373

¹ Abbreviations for craniometric variables are from Table 2.

kina (1987; Masson and Kiiatkina, 1981) studied 68 individuals both on site and in Dushanbe, Tajikistan. A total of 28 individuals from Altyn depe are curated at the Institute of Ethnography and Anthropology of the Russian Academy of Sciences, Moscow, and were examined by the author.

For maximum sample sizes for Geoksyur and Altyn depe cranial series, repeated measures analysis of variance tests were performed to assess the degree of interobserver error between Kiiatkina (1987) and the author (Table 3). These tests revealed no significant differences in metric assessments between observers for the 46 individuals measured in common. These results indicate that no systemic biases are encountered when pooling measurements. Pooling of data collected by Kiiatkina and the author resulted in a sample of 70 adult individuals with cranial remains (38 males, 32 females) from Geoksyur and 78 adult individuals with cranial remains (38 males, 40 females) from Altyn depe.

Abbreviations, sample sizes, and sample locations for all cranial samples are provided in Table 1 and Figure 1.

The degree of interobserver error between the author and assessors of non-Central Asian comparative cranial series was assessed by means of repeated measures analysis of variance (Hemphill et al., 1991; Hemphill, in press) and indicated no significant measurement differences between observers for individuals obtained from Tepe Hissar or Harappa (Cemetery R37, Cemetery H). Interobserver error could not be assessed for samples obtained from Shahr-i Sokhta or Timargarha.

TABLE 4. Mean values of craniometric variables

	GOL ¹	BEB	BFTB	NPH	NH	NB	OH	OB	BZB	IPL	IPB
Male sample²											
ALT	189.5	135.9	95.7	70.7	51.6	25.2	32.4	40.7	129.1	49.2	40.1
CEMH	188.2	141.3	96.3	67.9	50.8	26.3	32.9	41.3	134.8	45.7	39.5
DJR	186.9	134.7	94.6	69.9	50.7	24.8	30.9	37.5	131.3	45.1	39.5
GKS	190.1	134.5	96.0	71.1	52.0	25.5	33.0	40.1	127.6	47.2	38.3
HAR	187.3	134.5	95.8	69.2	51.4	26.5	33.2	41.4	131.5	49.1	38.9
KUZ	190.9	138.9	96.0	68.7	49.6	26.4	30.9	39.9	134.0	44.3	40.0
MOL	185.6	138.1	95.0	69.4	51.5	25.1	31.8	38.3	126.6	44.2	39.7
SAP	183.5	134.9	93.0	70.2	51.3	24.2	32.7	37.7	129.1	43.1	38.6
SHS	185.8	136.4	96.0	70.2	50.6	25.7	31.8	42.1	129.4	47.0	40.1
TH2	188.8	132.0	94.2	70.3	50.4	25.1	31.6	41.0	125.3	46.8	40.7
TH3	188.4	134.1	95.5	69.8	50.6	25.4	32.1	41.2	127.3	47.6	40.1
TMG	190.2	132.0	93.8	70.3	50.0	22.9	33.3	41.5	133.0	48.3	39.8
Female sample											
ALT	181.4	135.1	94.5	67.3	49.6	24.2	32.7	38.9	121.4	45.0	38.4
CEMH	179.2	132.4	92.5	62.7	46.0	24.4	33.3	39.9	119.5	44.2	35.1
DJR	184.7	134.0	93.8	69.5	50.2	25.6	33.0	38.5	123.9	42.5	39.5
GKS	185.8	132.9	93.7	69.8	50.9	25.2	32.9	39.0	123.4	45.5	38.1
HAR	180.9	132.1	93.2	66.2	48.3	24.2	34.1	40.6	123.9	45.1	36.4
KUZ	179.3	132.6	91.5	65.1	46.8	23.6	30.7	36.3	122.4	42.5	37.6
MOL	183.5	134.2	93.6	70.6	49.7	25.0	32.6	38.8	126.5	44.4	37.9
SAP	181.5	134.1	92.5	67.5	49.2	24.8	33.0	37.2	124.4	43.2	36.3
SHS	179.1	133.3	93.9	67.6	50.0	24.5	31.9	40.7	122.7	45.7	38.2
TH2	178.3	132.1	91.7	67.6	48.3	23.7	33.6	38.7	118.7	46.3	37.6
TH3	179.4	131.8	92.2	66.1	48.3	23.9	31.7	39.6	120.2	45.5	38.2
TMG	180.2	130.9	91.7	66.6	48.1	22.9	33.1	40.0	122.3	41.5	37.0
Sex-standardized sample											
ALT	185.5	135.5	95.1	69.0	50.6	24.7	32.6	39.8	125.3	47.1	39.3
CEMH	183.7	136.8	94.4	65.3	48.4	25.3	33.1	40.6	127.1	44.9	37.3
DJR	185.8	134.3	94.2	69.7	50.5	25.2	32.0	38.0	127.6	43.8	39.5
GKS	190.1	134.5	96.0	71.1	52.0	25.5	33.0	40.1	127.6	47.2	38.3
HAR	184.1	133.3	94.5	67.7	49.9	25.4	33.6	41.0	127.7	47.1	37.6
KUZ	185.1	135.7	93.8	66.9	48.2	25.0	30.8	38.1	128.2	43.4	38.8
MOL	184.5	136.1	94.3	70.0	50.6	25.1	32.2	38.6	126.5	44.3	38.8
SAP	182.5	134.5	92.7	68.8	50.2	24.5	32.9	37.5	126.7	43.1	37.5
SHS	182.5	134.8	94.9	68.9	50.3	25.1	31.8	41.4	126.0	43.3	39.1
TH2	183.5	132.1	93.0	69.0	49.4	24.4	32.6	39.9	122.0	46.5	39.1
TH3	183.9	133.0	93.9	69.9	49.4	24.7	31.9	40.4	123.8	46.5	39.1
TMG	185.2	131.5	92.7	68.4	49.1	22.9	33.2	40.8	127.7	44.9	38.4

¹ Abbreviations for craniometric variables are from Table 2.² Abbreviations for samples are from Table 1.

Methods

The covariance matrix for each sample is obtained for males and females pooled together with listwise deletion. Although pairwise deletion permits greater effective sample sizes within each sample, listwise deletion is used to avoid systematic biases caused by overrepresentation and underrepresentation of individual variables (Wilkinson, 1990). A pooled covariance matrix is obtained for all samples and bias-adjusted to accommodate differences in sample size. Variable averages are calculated for both males and females. Sex-standardized group values for each variable are obtained by taking the average of male and female mean values for each sample (Table 4). The bias-adjusted pooled covariance matrix and sex-

standardized group values are used to obtain Mahalanobis generalized distances (d^2) between each pair of samples. The diagonal matrix of Mahalanobis d^2 values is provided in Table 5. The significance of pairwise d^2 distance contrasts is assessed by means of F-tests conducted according to the method of Konigsberg et al. (1993).

The diagonal matrix of Mahalanobis d^2 values is used as input for cluster analyses. Different associating algorithms are used to provide two perspectives on the patterning of intersample phenetic affinities. These associating algorithms include the weighted pair average linkage method (WPGMA) (Sneath and Sokol, 1973) and the neighbor-joining method (Saitou and Nei, 1987; Felsenstein, 1989). The cophenetic correlation

TABLE 5. Matrix of Mahalanobis d^2 generalized distances¹

	ALT	CEMH	DJR	GKS	HAR	KUZ	MOL	SAP	SHS	TH2	TH3	TMG
ALT	0											
CEMH	3.471	0										
DJR	3.153	5.482	0									
GKS	1.159	3.813	2.583	0								
HAR	5.425	2.430	7.367	4.649	0							
KUZ	4.461	4.384	1.054	4.218	6.936	0						
MOL	1.749	3.951	0.498	1.822	5.982	1.430	0					
SAP	4.605	4.162	1.488	3.666	4.873	1.959	1.464	0				
SHS	2.737	4.291	3.850	3.896	7.117	4.318	2.689	5.908	0			
TH2	0.894	4.515	4.221	2.244	5.110	5.662	2.866	6.005	2.719	0		
TH3	0.673	3.632	4.029	2.017	4.946	4.789	2.680	5.968	1.683	0.399	0	
TMG	4.903	4.132	5.499	4.874	3.129	5.061	5.029	4.564	5.141	4.224	4.135	0

¹ Abbreviations for samples are from Table 1.

coefficient, r_{cs} (Sneath and Sokol, 1973), is computed with the NTSYS-pc statistical package to measure the degree of correspondence between the obtained phenogram from WPGMA cluster analysis and the original resemblance matrix.

The diagonal matrix of Mahalanobis d^2 values is used as input for nonmetric multidimensional scaling to provide a third perspective on the patterning of intersample affinities. Kruskal's stress formula number one (Kruskal, 1964a,b) is used to calculate distances between individual points. The goodness of fit obtained by multidimensional scaling is assessed through calculation of the degree of stress through 100 iterations. Multidimensional scaling is accomplished with the SYSTAT statistical package (Wilkinson, 1990). Results obtained are ordinated in three-dimensional space, and a minimum spanning tree (Hartigan, 1975) is imposed on the array of data points to ease interpretation of the patterning of intersample associations.

Principal coordinates analysis is used to provide a fourth perspective on intersample craniometric variation. Principal coordinates analysis is preferred over principal components analysis in situations in which the number of variables approaches or exceeds the number of samples compared (Hair et al., 1971). The symmetric matrix of Mahalanobis d^2 values is double-centered prior to entry into NTSYS-pc statistical software. The first three principal coordinate axes are retained, and group scores are calculated along these axes and ordinated into three-dimensional space. As with results from multidimensional scaling, a minimum span-

ning tree is imposed on the array of principal coordinate scores to ease interpretation of intersample associations. The cophenetic correlation coefficient is computed to assess the goodness of fit of the obtained eigenvectors with the matrix of Mahalanobis d^2 values. This latter step is especially important because the cophenetic correlation coefficient provides more information on the patterning of relative phenetic distances among samples than the absolute distance (as indicated by the percentage of total variation explained by the first three eigenvectors) (Rolf, 1972, 1994), and it is the patterning of these relative distances that is most useful for understanding processes of past population interactions.

As a final step in assessment of the nature of intersample craniometric variation, spatial distance and temporal distance matrices are computed among all sample pairs. Congruence between the Mahalanobis d^2 matrix and these latter two matrices is assessed by means of the Mantel test (Mantel, 1967) and Mantel correlation coefficient (Smouse et al., 1986). These procedures provide a test to determine if differences between samples may simply be a product of geographical propinquity or differences in antiquity. Significance of these associations is obtained through 1,000 permutations at random by rows and columns.

RESULTS

The bias-adjusted matrix of Mahalanobis d^2 values was calculated according to the procedures outlined above (Table 5). F-tests (Table 6) reveal that the majority of d^2 values between samples are significant (53/

TABLE 6. *F*-tests and probability values of pairwise Mahalanobis d^2 generalized distances¹

	ALT	CEMH	DJR	GKS	HAR	KUZ	MOL	SAP	SHS	TH2	TH3	TMG
ALT	—	0.000	0.000	0.003	0.000	0.000	0.006	0.000	0.000	0.614	0.012	0.000
CEMH	3.725	—	0.000	0.000	0.017	0.045	0.005	0.012	0.000	0.051	0.000	0.090
DJR	5.629	4.830	—	0.000	0.000	0.594	0.811	0.141	0.000	0.003	0.000	0.000
GKS	2.837	4.192	4.757	—	0.000	0.000	0.003	0.000	0.000	0.031	0.000	0.000
HAR	11.312	2.397	11.835	10.028	—	0.000	0.000	0.000	0.000	0.000	0.000	0.013
KUZ	4.353	2.321	0.849	4.212	6.238	—	0.445	0.318	0.000	0.032	0.000	0.065
MOL	2.692	3.103	0.612	2.886	8.348	1.029	—	0.227	0.000	0.068	0.000	0.005
SAP	5.981	2.841	1.565	4.888	5.779	1.226	1.366	—	0.000	0.004	0.000	0.024
SHS	7.243	4.958	7.564	10.727	16.490	4.523	4.520	8.316	—	0.006	0.000	0.000
TH2	0.827	2.275	3.234	2.124	4.364	2.611	1.963	3.580	2.697	—	0.928	0.145
TH3	2.299	4.870	9.716	7.230	14.433	5.780	5.419	9.917	6.693	0.454	—	0.000
TMG	4.284	1.972	3.989	4.354	2.527	2.208	3.264	2.579	4.807	1.751	4.422	—

¹ F values are below the diagonal. Probability values (*P* values) above the diagonal. Abbreviations for samples are from Table 1.

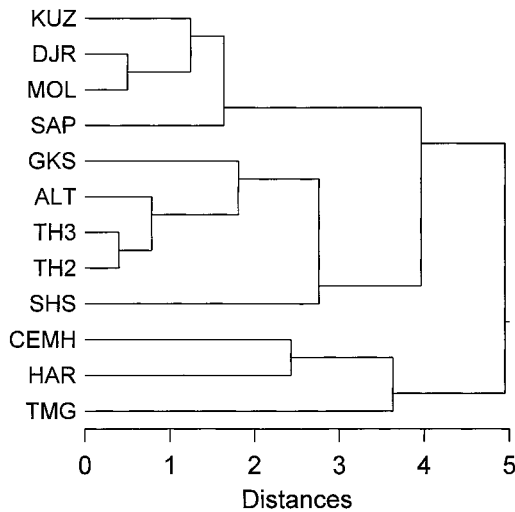


Fig. 2. WPGMA cluster analysis of Mahalanobis d^2 values. Branch points are euclidean distances. Abbreviations for samples are defined in the text.

66; 80.3%). Of the 53 pairwise contrasts exhibiting a significant difference, eight (15.1%) are significant at the 0.05 level, while 45 (84.9%) are significant at the 0.01 level.

WPGMA cluster analysis

The dendrogram obtained by means of the WPGMA associating algorithm (Fig. 2) indicates that Indus Valley samples not only occupy an outlier status relative to all other groups but also that these samples exhibit only marginal affinities to one another. The remaining samples are arranged in two distinct groups. The first encompasses all four samples from the north Bactrian oasis. The second includes all Iranian samples as well

as the two samples from Turkmenistan (ALT, GKS). Among north Bactrians, affinities are closest between Molali (MOL) and Djarkutan phase (DJR) inhabitants of Djarkutan, with the Kuzali phase (KUZ) sample from this site somewhat more distant. The earliest north Bactrian sample, Sapalli (SAP), exhibits a distant affinity to all other north Bactrians. Closest affinities in the second group occur between the two samples from the northern Iranian site of Tepe Hissar (TH2, TH3). The sample from Altyn depe (ALT) joins these two samples from Tepe Hissar at a more distant remove, followed by the sample from Geoksyur (GKS). The eastern Iranian sample from Shahr-i Sokhta (SHS) exhibits only a distant association to other Iranian and Turkmenian samples.

Neighbor-joining cluster analysis

Neighbor-joining cluster analysis (Fig. 3) provides a different representation of the distance matrix than that provided by WPGMA cluster analysis because it is an unrooted tree whose branches have different lengths. Long branch lengths may be interpreted as an indicator of a large degree of morphological separation, while short branch lengths are indicative of a small degree of morphological separation between samples. The neighbor-joining tree provides an array of intersample associations that are largely in agreement with those depicted by WPGMA (Fig. 3). That is, three geographical aggregations of samples may be identified. Indus Valley samples occupy the lower left of this array, Iranian samples the lower right, and north Bactrian samples the upper center. Indus Valley samples exhibit distant

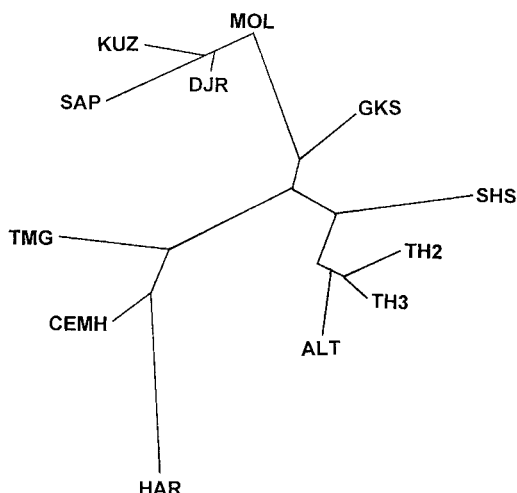


Fig. 3. Neighbor-joining tree based on Mahalanobis d^2 values. Abbreviations for samples are defined in the text.

affinities, both to one another and to all other samples included in this analysis. Among Iranian samples, affinities are close between the two northern Iranian samples from Tepe Hissar (TH2, TH3), while the eastern Iranian sample (SHS) is much more divergent. Neighbor-joining cluster analysis confirms that the later Turkmenian sample from Altyn depe (ALT) shares closer affinities to the northern Iranian samples from Tepe Hissar than does the eastern Iranian sample from Shahr-i Sokhta. Affinities among north Bactrian samples are also somewhat diffuse, but these four samples clearly exhibit closer affinities to one another than to samples from other regions. Except for a slight reversal of Djarkutan (DJR) and Kuzali (KUZ) phase samples, north Bactrians are arranged in reverse chronological order from the main line of intersample variation. That is, the most recent of the north Bactrian samples, Molali (MOL), possesses the closest phenetic affinities to samples from other regions, while the earliest, Sapalli (SAP), is the most divergent. In a departure from results obtained by WPGMA cluster analysis, nearest-neighbor analysis indicates that the earlier of the two Turkmenian samples, Geoksyur (GKS), represents the most proximate non-Bactrian sample to north Bactrians and exhibits

greater affinities to these samples than to samples from Iran (TH2, TH3, SHS) or to the later sample from Turkmenistan (ALT).

Cophenetic correlation coefficients

The cophenetic correlation coefficient for the degree of correspondence between the phenogram obtained by WPGMA cluster analysis and the bias-adjusted matrix of Mahalanobis d^2 values is somewhat low ($r_{cs} = 0.604$). This suggests that a fair amount of distortion is encountered when attempting to arrange intersample differences in cranio-metric variation in a hierarchical fashion through cluster analysis (Rolf, 1994).

Multidimensional scaling

Sneath and Sokol (1973) recommend that alternative methods of data reduction be used in cases where cophenetic correlations indicate that a fair amount of distortion of the original data matrix is incurred by hierarchical cluster analyses. Specifically, Sneath and Sokol recommend use of multidimensional scaling and principal coordinates analysis.

Multidimensional scaling of the bias-adjusted diagonal matrix of d^2 values into three dimensions with Kruskal's formula one is accomplished with a stress value of 0.048 after 100 iterations. This value falls within acceptable limits and indicates that multidimensional scaling of these data into three dimensions provides an array of intersample associations little affected by distortion. A plot of multidimensionally scaled values, with a minimum spanning tree imposed between individual data points, is provided in Figure 4.

An examination of this array confirms the presence of the three regional groups identified by nearest-neighbor cluster analysis (Fig. 3). Indus Valley samples all occupy the left side of this array and are not only the most divergent of the samples considered but also exhibit distant affinities to one another. The minimum spanning tree indicates that connections between Indus Valley samples and samples from other regions are closest between CEMH and the earlier sample from Turkmenistan (GKS), but this connection is not close. North Bactrian samples occupy the upper right of this array, and as

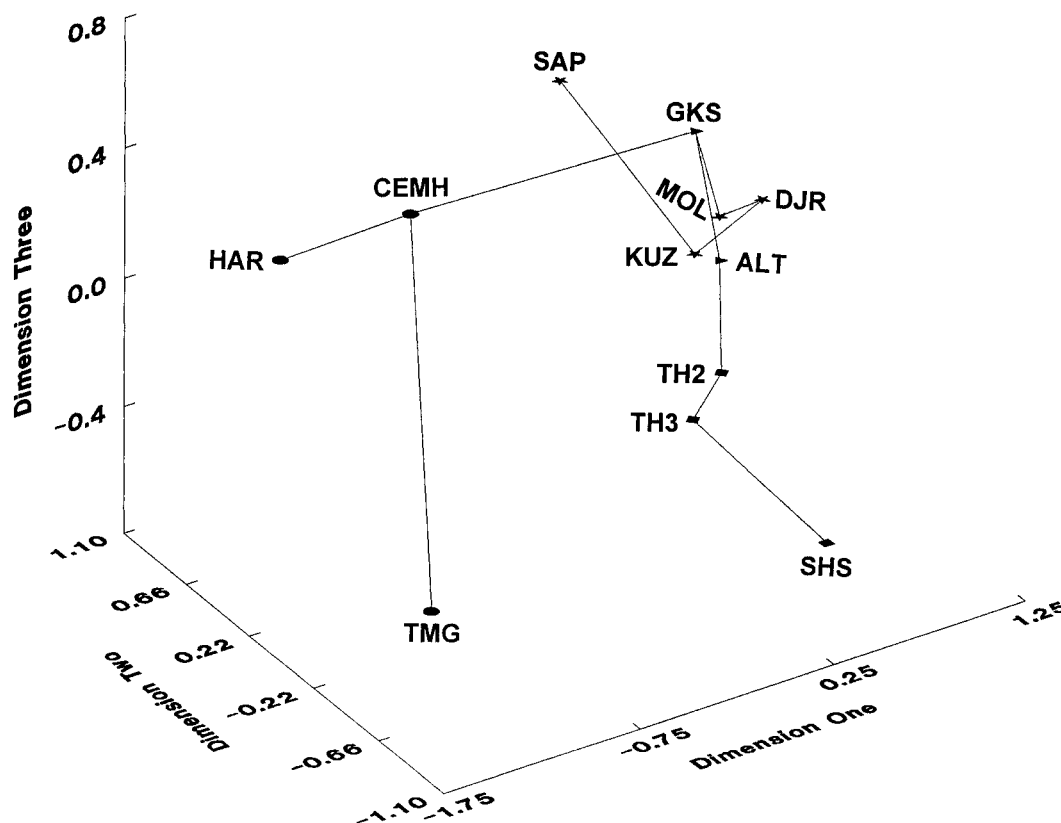


Fig. 4. Minimally spanned plot of sample values for the first three multidimensionally scaled dimensions. Sample symbols are the same as in Fig. 1. Abbreviations for samples are defined in the text.

indicated by WPGMA cluster analysis, associations among these samples are closest between the three chronologically successive samples from Djarkutan (DJR, KUZ, MOL), while the sample from Sapalli tepe (SAP) is markedly divergent. Confirming results obtained by neighbor-joining cluster analysis, the minimum spanning tree indicates that connections between north Bactrians and other regional samples are closest between the most recent of north Bactrian sample (MOL) and the earlier sample from Turkmenistan (GKS). Iranian samples occupy the lower right of Figure 4. Closest affinities among Iranian samples occur between the two samples from Tepe Hissar (TH2, TH3), while the eastern Iranian sample (SHS) is once again identified as the most divergent. Closest affinities between Iranian samples and samples from other regions occur between the earlier sample

from Tepe Hissar (TH2) and the later Turkmenian sample (ALT). Together, north Bactrians and Iranians share closer affinities to one another than either regional group shares with samples from the Indus Valley. Importantly, this array indicates that the two Turkmenian samples serve as a phenetic link between north Bactrians and Iranians in which the earlier of the two samples (GKS) shares closer affinities to north Bactrians, while the later Turkmenian sample (ALT) possesses closer affinities to Iranians (especially northern Iranians).

Principal coordinates analysis

A principal coordinates analysis of the double-centered Mahalanobis d^2 matrix yields three coordinate axes that combine to explain 93.2% of the total variance. Comparison of the eigenvector matrix with the d^2 matrix yields a cophenetic correlation coeffi-

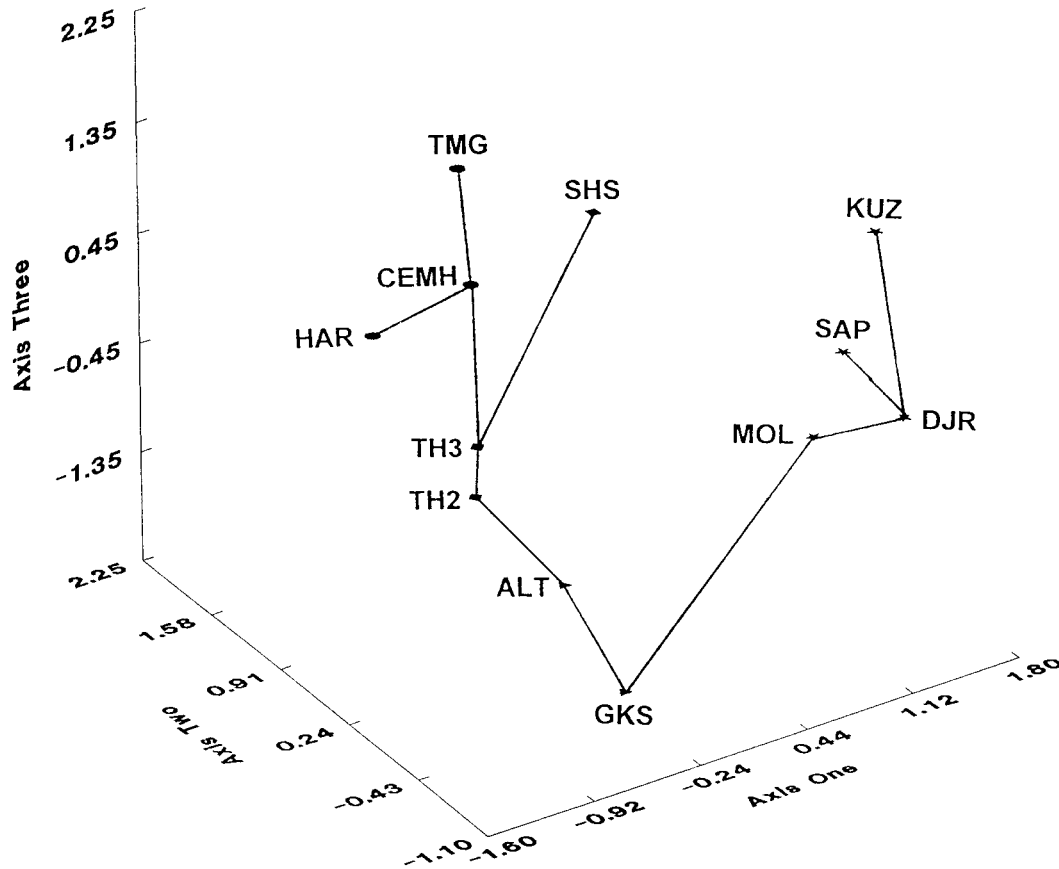


Fig. 5. Minimally spanned ordination of sample scores for the first three principal coordinate axes. Sample symbols are the same as in Fig. 1. Abbreviations for samples are defined in the text.

cient ($r_{cs} = 0.965$), which indicates that the first three eigenvectors provide an excellent fit of the data (Rolf, 1994). An ordination of group scores for the first three coordinate axes is provided in Figure 5, and a minimum spanning tree has been imposed on this array to clarify associations between samples. A different pattern of intersample variation is provided by this analysis. Perhaps the most striking difference is that principal coordinates analysis identifies north Bactrians rather than Indus Valley inhabitants as the most divergent of the regional aggregations of samples considered. Nevertheless, principal coordinates analysis confirms that north Bactrians possess closest affinities to other north Bactrians and Indus Valley samples possess closest affinities to other Indus Valley samples.

Principal coordinates analysis confirms the intermediate phenetic positioning of the two Turkmenian samples (ALT, GKS) between Iranians and north Bactrians. Just as depicted by nearest-neighbor cluster analysis and by multidimensionally scaling, the later Turkmenian sample (ALT) exhibits closer affinities to Iranians, while the earlier Turkmenian sample (GKS) possesses closer affinities to north Bactrians. Once again, closest affinities between north Bactrians and samples from other regions occurs between the most recent of the north Bactrian samples (MOL) and the earlier sample from Turkmenistan (GKS).

Mantel tests

The normalized Mantel statistic, which is equivalent to a correlation coefficient (r),

obtained between the Mahalanobis d^2 matrix and the matrix of chronological differences between samples, is -0.085. The permutational probability to observe a higher or equal correlation based on 1,000 permutations is $P = 0.303$. This value suggests that differences in antiquity, and hence the history of exposure to the selective pressures of agricultural subsistence, provide little explanation of the patterning of craniometric differentiation among these samples. Likewise, a comparison between the Mahalanobis d^2 matrix and the matrix of geographical distances between samples yields a correlation coefficient of $r = 0.090$. The permutational probability to observe a higher or equal correlation is $P = 0.313$. This suggests that geographic distance also provides little influence on the patterning of craniometric differentiation among these samples.

DISCUSSION

Three hypotheses have been advanced to account for the appearance of Oxus civilization populations within the oases of Bactria and Margiana during the final centuries of the third millennium BC. The hypothesis currently favored by the majority of archaeologists working Central Asia is the late colonization model (Askarov, 1974, 1977, 1981; Biscione, 1977; Gupta, 1979; Hiebert, 1994; Hiebert and Lamberg-Karlovsky, 1992; Lamberg-Karlovsky, 1994b; Masimov, 1981; Masson, 1981, 1988, 1989, 1992b; Masson and Sarianidi, 1972). This model holds that the oases of Margiana and Bactria were unoccupied prior to the Initial Late Bronze Age (before 2200 BC). Due to an "urban crisis" that affected the urban centers of the Kopet Dag foothill plain during the Late Middle Bronze Age, inhabitants of these urban centers (such as Altyn depe) embarked on a wholesale colonization of Margiana and Bactria.

If this hypothesis is true, we expect the earliest Oxus civilization inhabitants of the Bactrian oasis to be these "colonists" from the Middle Bronze Age urban centers of the Kopet Dag foothill plain. Since this interaction is held to be one of wholesale colonization, the earliest sample from the north Bactrian oasis (Sapalli) ought to be virtually identical to the Middle Bronze Age sample

from Altyn depe. Later Bactrian samples should also exhibit close phenetic affinities to Altyn depe but may be sequentially more divergent over time due to genetic drift or founder effect if the founding population was relatively few in number. The sample from Geoksyur should exhibit second closest affinities to north Bactrians since the majority of late colonization model proponents maintain that the bulk of the Late Aeneolithic population of Geoksyur fled to Altyn depe (e.g., Gupta, 1979; Masson, 1991a; Tosi, 1973–1974) at the beginning of the Early Bronze Age (Namazga IV: 3000–2500 BC) (Kohl, 1992). Iranian populations and populations of the Indus Valley are thought to have played no role whatsoever in the origins of Oxus civilization populations, and hence we expect samples from the latter two regions to be markedly divergent from north Bactrians.

The results of this analysis provide no support for the late colonization model. Despite myriad similarities in material culture shared between the Bactrian-Margiana archaeological complex of the Oxus civilization (Hiebert, 1994) and Late Middle Bronze Age Namazga V assemblages of the Kopet Dag foothill plain from Altyn depe (levels 0–2) (Masson, 1988; Udemuradov, 1987), all analyses of phenetic relationships refute any notion of wholesale colonization by populations from the Kopet Dag to the north Bactrian oasis. Regardless of the technique employed, all statistical analyses indicate a profound phenetic separation rather than close phenetic affinity between Altyn depe and the earliest north Bactrians (SAP). What similarities do exist between north Bactrians and Altyn depe occur with the latest of the north Bactrian samples, Molali (MOL). However, contrary to the expectations of the late colonization model, these affinities are closer to the earlier Turkmenian sample from Geoksyur than to Altyn depe.

In addition, all phenetic analyses reveal a consistently closer affinity between Altyn depe and the northern Iranian samples from Tepe Hissar (TH2, TH3) than between Altyn depe and north Bactrians. One possible explanation for this pattern is that the abandonment of Kopet Dag-affiliated sites located in the upper Atrek Valley and the

Darreh Gaz plain of Iranian Khorassan (Kohl, 1981, 1984; Kohl et al., 1982; Kohl and Heskell, 1980) at the end of the Early Bronze Age could have resulted in the emigration of some members inhabiting these sites to Altyn depe. Absorption of these Khorassian populations may have served to enhance affinities between the population of Altyn depe and those of northern Iran (Tepe Hissar II).

Another intriguing aspect of the suite of phenetic affinities exhibited by the Middle Bronze Age sample from Altyn depe concerns possible repercussions caused by abandonment of the Tedjen River delta at the end of the Late Aeneolithic period (c. 3000 BC). If it is true that the bulk of the population of Geoksyur fled to Altyn depe (see Gupta, 1979; Tosi, 1973–1974), this may indicate what little affinity is exhibited by Altyn depe to north Bactrians is simply a reflection of the interaction between the refugees of the desiccated Tedjen River delta and north Bactrians (see below). As such, these results in no way reflect any direct genetic contribution from the Middle Bronze Age inhabitants of Altyn depe in the formation of the Oxus civilization population of the north Bactrian oasis.

The most complex model offered to account for the origins of Oxus civilization populations is the trichotomy model. This model holds that the oases of Bactria and Margiana were occupied prior to the appearance of the Oxus civilization (Udemuradov, 1988). This model also holds that Oxus civilization populations in Bactria and Margiana experienced markedly different histories (P'yankova, 1993). In Bactria, the presence of the Harappan outpost of Shortughai, located in the eastern Bactrian oasis of Afghanistan, has been cited by Francfort (1984) as evidence of possible gene flow between an Harappan-affiliated population, whose ultimate origins are the Indus Valley, with local Neolithic residents. In Margiana, the early appearance of late phase Middle Bronze Age artifacts in the Kellei sub-oasis (Hiebert, 1994; Masimov, 1979; Masson, 1964, 1992b; Masson and Sarianidi, 1972; Sarianidi, 1990) is interpreted as evidence of possible gene flow between Kopet Dag foot-

hill populations and local Margiana residents (P'yankova, 1993).

If this model is true for Bactrian populations, we expect north Bactrian samples, especially the earliest, Sapalli (SAP), to exhibit affinities to Indus Valley samples. Since the nature of this interaction is maintained to be one that involves an unspecified level of gene flow between Harappan-affiliated populations and a local pre-Oxus civilization population, affinities between the sample from Sapalli and samples from the Indus Valley may not be close, especially if gene flow from Harappan-affiliated populations was limited in intensity. Later north Bactrian samples (DJR, KUZ, MOL) should exhibit sequentially more distant affinities to Indus Valley samples due to the abandonment of lapis lazuli mining at Shortughai and dissolution of the Harappan Civilization around 2000 BC (Francfort, 1981a,b, 1984, 1989). Since no other regional populations are believed to have contributed to the origins of Bactrian Oxus civilization populations, there should be no affinities between north Bactrian samples and samples from either Turkmenistan or Iran.

The results obtained in this analysis offer little support for the trichotomy model. While the array of multidimensionally scaled Mahalanobis d^2 values (Fig. 4) suggests some affinity between Sapalli (SAP) and Indus Valley samples (especially the late Harappan sample [CEMH]), this affinity is neither identified by the minimum spanning tree imposed upon this array nor by any other statistical analysis. Rather, WPGMA cluster analysis indicates that north Bactrian samples exhibit closer affinities to Iranian and Turkmenian samples, while neighbor-joining cluster analysis and principal coordinates analysis indicate that north Bactrians are a unique phenetic group unto themselves with only a distant affinity to the Late Aeneolithic sample from Turkmenistan (GKS).

Although the results obtained here indicate that local populations contributed to the origins of the Oxus civilization inhabitants of the north Bactrian oasis, they do not support the expectation of contribution from Harappan-affiliated populations whose ultimate origins are the Indus Valley, for north

Bactrian samples do not consistently exhibit closer affinities to Indus Valley samples than to non-Bactrian samples from other regions. Whether the expectations that Oxus civilization populations of Margiana will differ markedly from those of Bactria and that Middle Bronze Age Kopet Dagh foothill plain populations contributed to the origins of these Margianans cannot be evaluated until skeletal remains from Margiana become available.

The assertion that some local population must have contributed to the formation of Oxus civilization populations is compelling. Calculation of total estimated site area for the Middle Bronze Age period in the Kopet Dagh foothill plain yields a value of only 95 hectares. By contrast, Oxus civilization sites in the oases of Bactria and Margiana encompass over 335 hectares (Biscione, 1977; Kohl, 1984). Although Sarianidi (1981, 1990) has attempted to reduce this discrepancy by arguing that not all of the Margiana sites were occupied at any given time (about one-third), this dramatic difference in total settlement area strongly suggests that some local population likely formed a major component of the Late Bronze Age occupants of Oxus civilization urban centers.

The third model offered to account for the origin of Oxus civilization populations is the early influence model. Proponents of this model emphasize the similarities in irrigation technology, oasis-based settlement strategy, and economic exchange patterns shared between the Aeneolithic Geoksyur culture of the Tedjen River delta and the Late Bronze Age Oxus civilization of Bactria and Margiana (Kohl, 1981, 1984, 1992). Discovery of Geoksyur-style ceramics in the Kelleli sub-oasis of Margiana (Masimov, 1979), as well as at the site of Sarazm in the middle Zeravshan Valley (Isakov, 1981, 1994; Isakov et al., 1987; Isakov and Lyonnet, 1988; Kohl, 1981, 1984, 1992; Masson, 1992b) immediately north of the Bactrian oasis, is held as evidence that the bulk of the Late Aeneolithic inhabitants of the Tedjen River delta fled to the northeast when the Tedjen River retracted to the south around 3000 BC. Proponents of this model suggest that the Oxus civilization populations of Bactria and Margiana owe their origins to limited but sig-

nificant gene flow between the refugees of the Tedjen delta and local Neolithic populations.

If this hypothesis is true, we expect north Bactrians, especially the earliest sample, Sapalli (SAP), to reflect the impact of this gene flow by exhibiting closer affinities to the Late Aeneolithic sample from Geoksyur (GKS) than to any other non-Bactrian sample included in this analysis. Since this interaction is held to be one of limited gene flow rather than wholesale colonization, the phenetic proximity between north Bactrians and Geoksyur may not be especially close. Nevertheless, since all other regional populations, such as those from Iran, the Indus Valley, and the Kopet Dagh foothill plain (Altyn depe), are not believed to have played any role in the origin of Bactrian Oxus civilization populations, we expect these samples to differ markedly from north Bactrians.

The results of this analysis confirm that north Bactrian samples share closer phenetic affinities to the Late Aeneolithic sample from Geoksyur than to any other samples. This pattern was obtained by all analytic techniques except WPGMA cluster analysis, which indicated that north Bactrians were equally divergent from all Iranian and Turkmenian samples. However, contrary to expectations of the early influence model, neighbor-joining cluster analysis, multidimensionally scaled d^2 values, and principal coordinates analysis all consistently indicate that closest affinities between Geoksyur and north Bactrians occur with the most recent sample (MOL), not with the earliest sample (SAP). This finding indicates that while the descendants of the Geoksyur culture may have played a role in the formation of Oxus civilization populations in the north Bactrian oasis, the origins of these populations are more complex than accounted for by the early influence model.

There are two possible explanations for the unexpected affinity between the Late Aeneolithic sample from Geoksyur and the most recent of the Late Bronze Age north Bactrian samples (MOL). It may be that interaction (i.e., gene flow) between the refugees of the desiccated Tedjen River delta and local Neolithic populations of Bactria was of an extremely limited nature and of long-

standing duration. If so, such limited gene flow may have taken place for centuries between the descendants of the Geoksyur culture, located in either northern Margiana or the middle Zeravshan Valley (Sarazm), and local inhabitants of the north Bactrian oasis. Because this interaction was of a limited nature, the results would show that no appreciable reduction in phenetic distance occurred until the beginning of the first half of the second millennium BC. Hence, a model predicated upon continuous low-level gene flow should be reflected by a steady but uniform reduction in phenetic distance between the Late Aeneolithic sample from Geoksyur and north Bactrians as one moves from the earliest sample (SAP) to the most recent sample (MOL).

A second possibility is that gene flow between these two populations may have been substantial but occurred at a more recent point in time. If true, north Bactrian samples that postdate this change in interpopulation interaction patterns should exhibit markedly closer phenetic affinities to the Late Aeneolithic sample from Geoksyur than samples that antedate this shift. Once this shift occurred, continued genetic exchange between north Bactrians and the descendants of the Late Aeneolithic Geoksyur culture should be reflected by subsequent north Bactrian samples exhibiting a sequential reduction in phenetic distance to the sample from Geoksyur.

An examination of d^2 distances separating north Bactrian samples and the Late Aeneolithic sample from Geoksyur (Table 5) indicates that, with the sole exception of the Kuzali phase sample, all other samples exhibit a sequential reduction from the Sapalli phase to the Djarkutan phase to the Molali phase. Results obtained from neighbor-joining cluster analysis, multidimensional scaling, and principal coordinates analysis consistently indicate that, apart from somewhat anomalous Kuzali phase sample, the Djarkutan phase inhabitants of the north Bactrian oasis are marked by a profound reduction in phenetic distance from the Late Aeneolithic Geoksyur sample and that this rapprochement continues with later Molali phase inhabitants. Together, the patterning of these results provides little support for

early, low-level gene flow but are largely in accord with patterns expected from stronger but more recent interaction. Thus, it appears that a change in interpopulation interactions occurred in the north Bactrian oasis and that this change took place at some point between the Sapalli phase and the Djarkutan phase (c. 2000 BC).

The suggestion of a shift in interregional contacts by Oxus civilization populations around 2000 BC is strengthened by several lines of archaeological evidence. This evidence may offer some insight into the ultimate origins of the local Bactrian population as well as the motivations behind such a shift in contacts once the Oxus civilization was fully under way. During the course of excavations at Sapalli tepe, graves were located within the habitation area, and silk remains were found in four of these graves as well as hundreds of millet seeds (cf., Askarov, 1974, 1977, 1981). While silkworms are indigenous to southern Central Asia, this discovery raises questions concerning contacts between the north Bactrian oasis and western China, since cocoons of silkworms have been recovered from fifth millennium BC Yang-shao sites in northwestern China (Chang, 1977). Kohl (1981) notes that compartmented bronze seals occur repeatedly in Bactrian sites and that these seals closely resemble those collected by Christian missionaries during the 1920s in the Ordos region of western China (Hambis, 1956; Pelloit, 1931–1932).

Recent metallurgical analyses of bronze objects from Bactria indicate significant compositional differences from those obtained from either Margiana or the Kopet Dagh foothill plain. Although the finished bronze objects are stylistically similar in all of these areas, bronzes in Bactria were produced by alloying copper with tin, but in Margiana and at Altyn-depe bronzes were produced by alloying copper with arsenic and lead (Gupta, 1979; Hiebert and Dillick, 1993; Masimov, 1981; Masson and Kiiatkina, 1981). The importance of this finding is twofold. First, the best source for tin in this region of the world lies to the northeast of the north Bactrian oasis—in the Ferghana Valley, the gateway between western China and central Asia (Gupta, 1979; Kohl, 1984; Masson,

1992a; Tosi, 1973–1974). Second, tin alloyed bronzes first appear in the archaeological record at Khapuz depe in the Tedjen River delta during the Early Bronze Age (3000–2500 BC) (Kohl, 1992).

By contrast, no silk remains or millet seeds have been recovered from the much more extensive excavations at Djarkutan (Askarov and Abdullaev, 1983). In addition, inhumation patterns at Djarkutan are different from those at Sapalli tepe, for graves now occur in a separate cemetery rather than in the habitation area. Inhumations in cemeteries outside the habitation area are documented in the Tedjen River delta, both at the Late Aeneolithic site of Geoksyur and at the Early Bronze Age site of Khapuz depe (Kohl, 1984). These data provide evidence to support the suggestion that Bactrian Oxus civilization inter-regional contacts shifted so that interactions with western China ceased and were replaced by more intensive contacts with the Middle Zeravshan Valley after 2000 BC.

CONCLUSIONS

The results of this study corroborate and refine results obtained in an earlier study (Hemphill, 1998). That is, Oxus civilization populations of the north Bactrian oasis (2200–1500 BC) appear to be the product of a local population, whose ultimate origins remain unknown, that experienced gene flow from populations to the west. Inclusion of samples from Turkmenistan permit identification of this gene flow as stemming from the Late Aeneolithic (3500–3000 BC) inhabitants of the Tedjen River delta (Geoksyur). Given the separation, both in time and in geographic distance, it is unlikely that this gene flow was one of direct interaction between populations of these two regions. Rather, the presence of Late Aeneolithic and Early Bronze Age (3000–2500 BC) Geoksyur-style ceramics in the Kelleli sub-oasis of Margiana and at the site of Sarazm in the middle Zeravshan Valley suggest that this gene flow likely occurred between the descendants of the refugees from the desiccated Tedjen River delta and local inhabitants of the north Bactrian oasis (Hissar culture). The phenetic affinities exhibited by the Late Aeneolithic sample from the Tedjen River

delta (Geoksyur) stand dramatically opposed to any claim that this population is the product of immigration from Iran (Masson and Sarianidi, 1972; Sarianidi, 1965; Masson, 1992a; but see Khlopin, 1964, Gupta, 1979, Kohl, 1981, 1984, 1992).

Although the ultimate origin of the local, Neolithic populations of the north Bactrian oasis remains unknown, recovery of silk and millet seeds from the earliest deposits at the site of Sapalli tepe (c. 2200–2000 BC) may indicate that these populations owe their ultimate origins to the northeast—to the Ferghana Valley of eastern Uzbekistan and to the western margin of western China. Absence of both silk and millet from later Oxus civilization deposits in the north Bactrian oasis may indicate that contacts changed with the rise of this civilization. The markedly reduced phenetic distances between Djarkutan and Molali phase samples from the site of Djarkutan and the Late Aeneolithic sample from the Tedjen River delta (Geoksyur) may indicate that contacts with western China ceased and were replaced by more intensive contacts with the Middle Zeravshan Valley after 2000 BC. Recovery of bronze objects whose composition reflects an alloying of copper with tin suggests the motivation for these enhanced contacts was access to the tin deposits of the Ferghana Valley to the northeast.

Despite myriad similarities in material culture, the results of this study repudiate claims that the Oxus civilization inhabitants of the north Bactrian oasis are the product of wholesale colonization from the Middle Bronze Age (2500–2200 BC) urban centers of the Kopet Dag foothill plain (i.e., Altyn depe). Instead, what meager affinities to north Bactrian samples are exhibited by the sample from Altyn depe may simply be a consequence of limited immigration to Altyn depe from the Tedjen River delta at the beginning of the Early Bronze Age (see Gupta, 1979; Tosi, 1973–1974). The greater affinities to northern Iranian samples (TH2, TH3) exhibited by the Middle Bronze Age sample from Altyn depe, coupled with abandonment of Kopet Dag-affiliated sites in Iranian Khorassan, may indicate that affinities were enhanced by absorption of these

Iranian populations at the beginning of the Middle Bronze Age.

The results of this study also stand opposed to models that call for any participation by Harappan-affiliated populations in the formation of north Bactrian Oxus civilization populations. Despite the presence of a well-documented Harappan outpost at Shortughai in the eastern Bactrian oasis, there is no evidence for even limited genetic contributions from any Harappan-affiliated populations, whose ultimate origins are the Indus Valley, to the Oxus civilization populations of the north Bactrian oasis.

Although intriguing, the exact nature of interaction between the descendants of the Geoksyur culture, the pre-Oxus civilization inhabitants of Bactria, and possible connections to western China will have to remain unresolved until skeletal samples from Sarazm, Margiana, and western China become available. Nevertheless, it is clear from the results of this study that neither wholesale colonization from the urban centers of the Kopet Dagh foothill plain nor gene flow from Harappan-affiliated populations from the Indus Valley appears to have played a role in the origins of the Oxus civilization populations of the north Bactrian oasis.

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